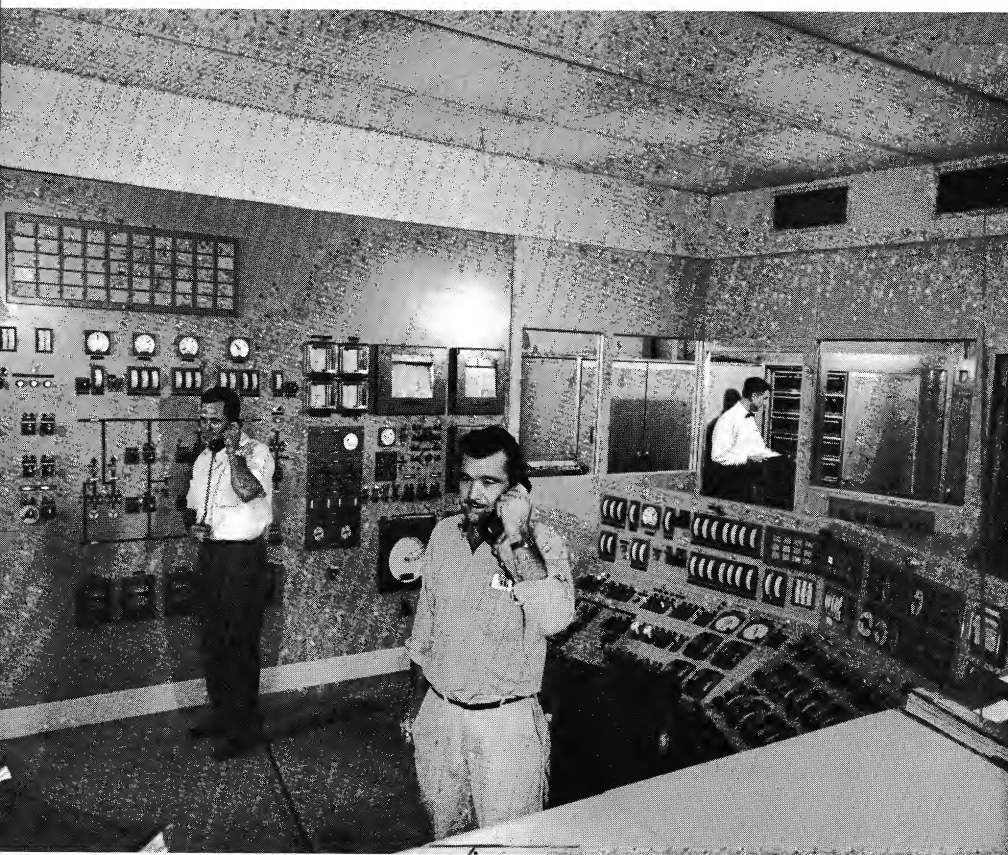


Power

the magazine of
energy systems engineering

SEPTEMBER 1964 • ONE DOLLAR • A MCGRAW-HILL PUBLICATION

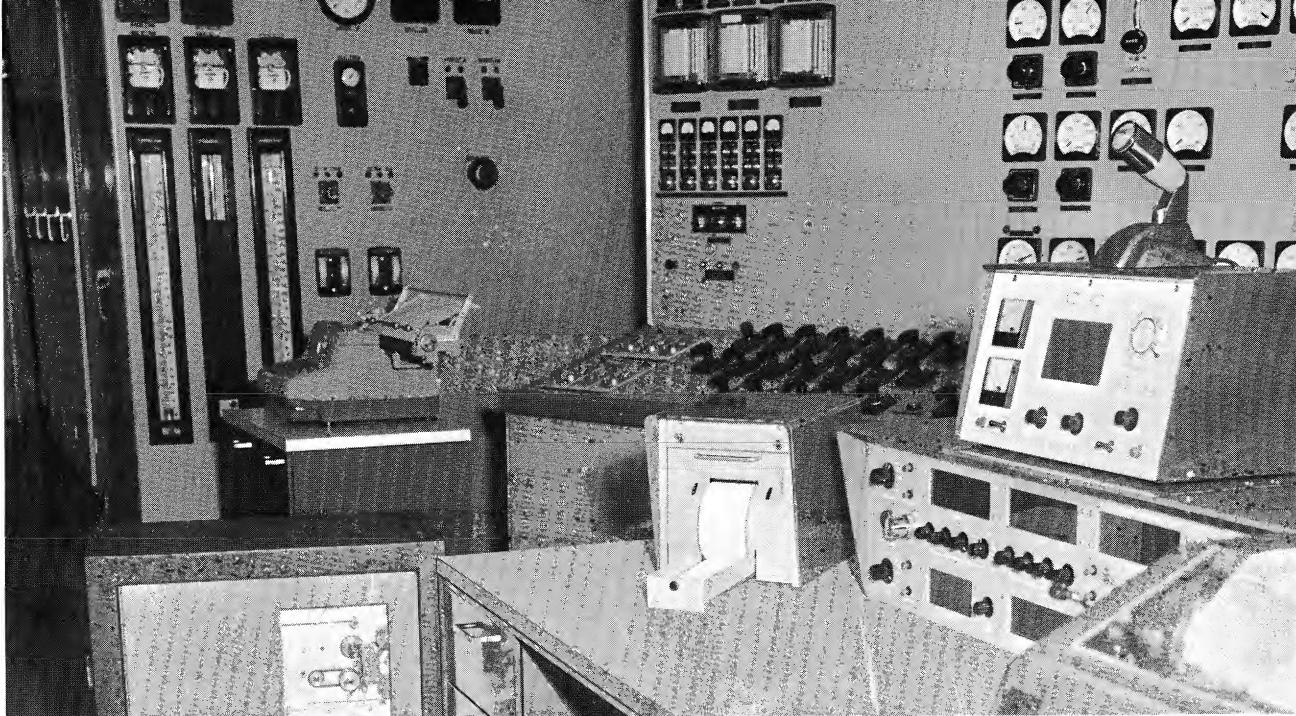


COMPUTER CONTROL:

Power plants join
an industry-wide
advance

Also in this issue

- Central HTW plant promises lower building and maintenance costs 67
- How cooling systems improve diesel performance, up thermal efficiency . . 71
- Batteries meet critical pipeline needs for emergency power 76
- A new way to continuously monitor spinning turbine shaft and blades 78
- Flow diagram helps simplify selection of gas-sampling systems 84
- Testing installed electric equipment can reduce costly shutdowns 86



RCA 110 COMPUTER monitors operations of two generating units from central control room. Voice alarm system comprises annunciator console (right) and tape storage unit for recordings (left). Microphone transmits new announcements to tape unit

Growing complexity of modern control room instrumentation can slow down operator's reaction to warning signals. Now at Gulf States Utilities' Riverside plant . . .

Recorded voice warns of plant trouble

Growing acceptance of data-logging and computer process control installations in modern power plants has led to an unexpected problem—that of deciphering the mass of information presented to the human operator.

Continuously scanning several hundred operating parameters, the computer prints this data and checks it against normal operating conditions. Should one or more points be off-normal, the computer or data-logger initiates an audible alarm signal to attract the operator's attention. The operator must then decipher the often cryptic information printed out by the machine. Adding to the operator's difficulty is the speed with which the data is presented and its timing in relation to other activities.

Neither of these problems is limited to plant operators. On board airplanes, where there is even more complex equipment, systems designers have searched for better means of data presentation. Most common approach is the attempt to make the machine more "human"; it is this technique which Tel-a-Dex Corporation has adopted in Gulf States Utilities' Riverside plant at Lake Charles, La.

Combined with an RCA 110 computer controlling Riverside's two peaking units (thermal plants developing 35 and 40 mw respectively), the Tel-a-Dex installation comprises an audible annunciator coupled to a continuous loop 16-track tape recording system. When the computer recognizes an out-of-normal signal to the data-logger, it addresses both alarm printer and tape storage unit

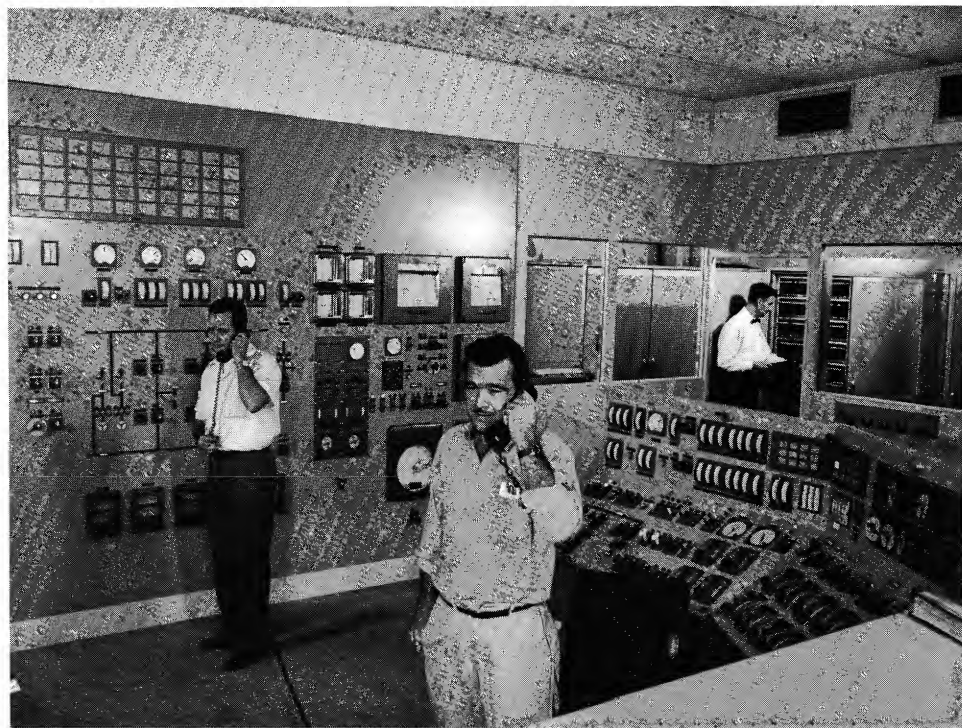
simultaneously. While the printer types a record of the alarm occurrence, the tape unit is searching its file of 256 prerecorded vocal messages for the one message stating what alarm signal has been received. As soon as it is located, at most in three seconds, the message is broadcast over the annunciator. To avoid confusion, Unit 1 voice alarms have been recorded by a female and Unit 2 by one of the male operators.

At certain times off-normal points will occur faster than they can be announced. The computer is programmed to store these points and announce them either in the order they occurred or in order of their priority. Thus, in the event of simultaneous receipt of "burner No. 4 flame failure—oil valve not closed" and "boiler blowdown conductivity high" signals, the computer will hold the latter until the Tel-a-Dex has announced the more important flame loss warning.

Alarm warnings and remedial instructions can both be prerecorded on the tape unit. Dialing a three-digit address number to locate a particular length of tape, programmer reads the announcement into a recording microphone. Subsequent changes automatically erase any previous message. Experience so far has shown that the installation is trouble-free and a useful supplement to conventional warning systems. Says Riverside's Superintendent: "... attention is directed to the trouble area faster without the need to decode printed digital data."

CONTROL ROOM of modern thermal power plant houses computer, print-out units

COMPUTER CONTROL:



Power plants join industry-wide advance

With more than 400 industrial process computers ordered or in use, central-station engineers are leading the way to a new appreciation of automatic control technology

By R K EVANS, Assistant Editor

Reprinted from:

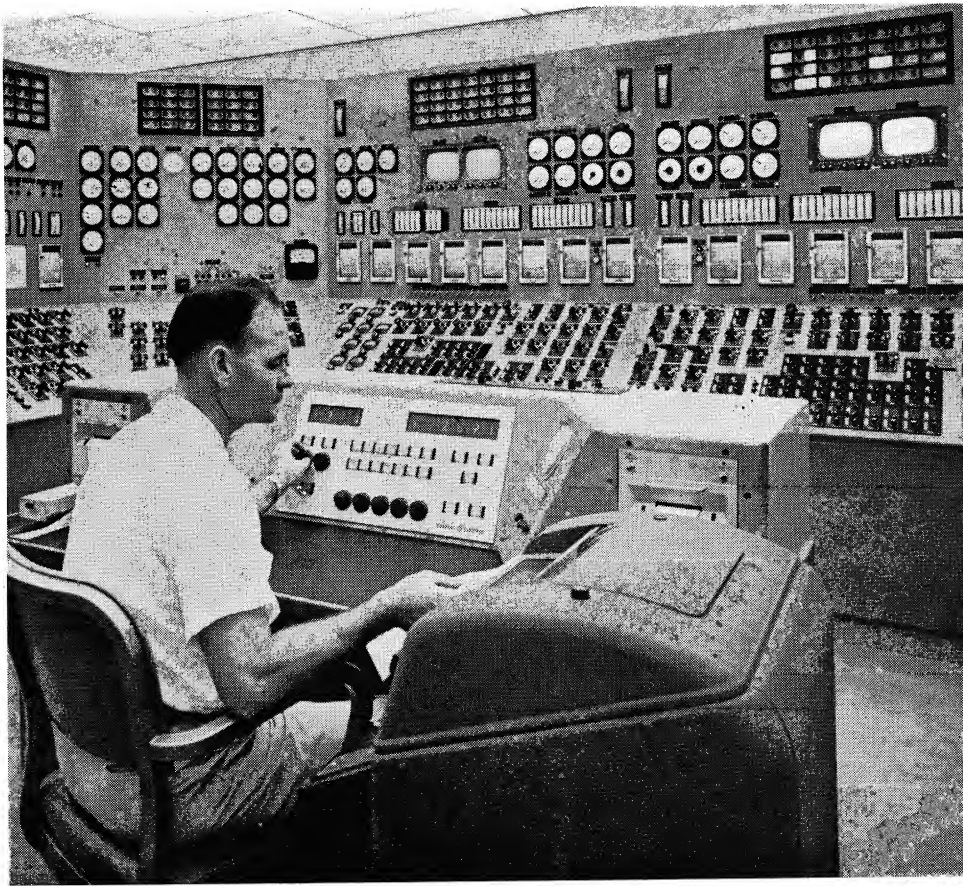


THE
SEPTEMBER 1964
ISSUE

A McGraw-Hill Publication
330 West 42nd Street
New York, N. Y. 10036.
©McGH Pub. Co., 1964

Evolution of electronic computers can be divided into five-year periods, each characterized by some significant development or trend. From 1945 to 1950 there was a period of fundamental electronic design which gave birth to today's computer "hardware." From 1950 to 1955 attention was focused on the solution of scientific and engineering problems, and the next five years saw a great upswing in commercial data-processing applications. Today there is comparable activity in the field of real-time, on-line computer control of paper and steel mills, power plants and refineries.

What problems have been encountered in today's computer applications? What developments will take place in the next few years? On the following pages, as we study two typical "case histories," we will discuss the lessons learned and the trends established in modern process plant control.



GEORGIA POWER COMPANY'S McDonough plant uses digital computer to monitor two 250-mw units. Operator inserts fuel analysis data to obtain continuous record of heat rate

First requirement...

When Georgia Power Company planned two 250-mw coal-fired units at its new McDonough plant, a decision was made at the design stage to incorporate digital computer monitoring. Behind this decision lay three compelling reasons:

(1) Existing boiler control problems increase with size of unit; continual adjustment of reset, rate and proportional band settings of conventional subloop control systems may be necessary to obtain stable control conditions. (2) Cracking of turbine metals, failure of boiler tubes and maintenance problems can often be attributed to wide and frequent variations in steam pressures and temperatures, both of which can be held within narrower limits under computer vigilance.

(3) To obtain maximum usefulness from the Southern Company's Early Bird computer, controlling dispatch and transmission over the four interconnecting systems of which Georgia Power is one, more accurate loading information had been found necessary from each of the system's thermal and hydro generating plants.

The resulting analysis of boiler-tur-

Analysis of plant operation precedes choice of computer

Today's engineers are finding greater justification for installing computer systems. Multiprogramming, long under development, is now established and available in many computers. Thus, an on-line system can handle data-processing or perform calculations during pauses between its real-time control activities.

More important, users are gaining in knowledge and sophistication in their choice of equipment. No longer entirely dependent on the computer hardware manufacturer for system design, a user finds it easier to apply computer control techniques to the requirements of his particular plant, whether it is a steel mill or bakery, sugar refinery or boiler-turbine unit.

First step following the decision to streamline plant operations by installing computer control is a searching analysis of the process itself. Many of the early failures of loudly-heralded computer-controlled plants were due to neglect of this fundamental requirement. One approach is to build a mathematical "model" of the individual plant components and their dynamic behavior. This can serve as a basis for the proposed computer program.

But success of an on-line computer depends very largely too on the accuracy and reliability of the basic measuring

instruments, sensors and transducers. Many pioneer efforts were unsuccessful because of the accumulation of errors as instrument readings were converted to digital form for processing by the computer and later reconverted to analog input to pneumatic or electric actuators. Account of McDonough plant above emphasizes the importance of recognizing sensor and instrument limitations *before* considering a computer program.

From data obtained during this preliminary plant analysis, the potential user can specify the tasks which a control-computer installation must be able to perform. Such criteria as cost, reliability, ease of programming, and life expectancy must all be taken into account. So must "maintainability"—too often, in the past, diagnosis and location of a fault have lengthened computer down time to an unnecessary and uneconomic degree.

Expensive result of neglecting these criteria was experienced by Southern California Edison at its Huntington Beach power plant, which, like Louisiana Power & Light Co's Little Gypsy, was one of the first units designed for on-line computer control. Plagued by such fundamental problems as inaccurate sensors and recording instruments, poor reliability of computer components, and

...increase the accuracy of plant instrumentation

bine system dynamics has served as a model for many subsequent computer-monitoring installations. At the time that work on McDonough started, little was known of boiler dynamics. Both analog and digital computer simulation was developed to establish primary and second-order effects and determine what data is relevant in deriving basic constants. For instance, drum pressure is not solely a function of fuel rate, but also of feedwater flow, burner position, gas recirculation, superheat spray water flow, waterwall slagging and other factors. Extensive study was therefore made of the cross-effects between these variables and of the best way to incorporate them into an overall control system.

Most far-reaching of the findings was the need for much greater accuracy in critical sensors and transducers when their signals form the input to an on-line digital computer. The four major types of measurement—pressure, temperature, flow and power output—were found to require a maximum error of $\pm 0.25\%$ of the measured variable if input error to the computer was to be held within acceptable limits.

Primary flow measurement selected was that of condensate to the deaerating heater. A flow section with removable throat-tap flow nozzle calibrated over a Reynolds Number range from 2×10^6 to 6.5×10^6 , enables differential pressure across the flow nozzle to be measured by a manometer with a servo-system following the mercury level. Latter is indicated by digitizer attached to a rotating shaft in the servo system; computer senses this as various combinations of contact closures.

Pressure measurement is through accurate pressure transducers with a long-term accuracy of $\pm 0.15\%$. Input to the computer is digital in binary-coded decimal form; pressure is read in 300 milliseconds with a resolution of one part in 2500.

Temperature readings are the only critical measurements requiring analog-to-digital conversion. Chromel-constantan thermocouples are duplicated where temperatures have greatest influence on results. Reference junctions and thermocouple elements are made of selected and matched wire, and are controlled to within 0.1 deg of set point.

Power measurement is through a three-element watt-hour meter system using calibrated current and potential transformers. Three-phase calibration minimizes the effect of mutual induction between coils when currents and potentials have phase relationships 120 deg apart, insuring the desired accuracy.

On-line computer selected for monitoring the McDonough units is a General Electric GE-412 digital stored-program unit, with a 256-input, 20-point memory event recorder directly coupled to the computer to monitor sequence of events during abnormal operation. Under normal conditions memory is available for alarm storage.

In operation, fuel analysis and similar data are inserted via the operator's console. Results of performance calculations (boiler efficiency, heat rate, and divergence from reference cycle) together with continuous pressure, temperature and flow readings are typed out on the console typewriter. Information, such as boiler and turbine efficiencies, is also available for visual display and trend recording, affording a continuous check on operation.

need for frequent program changes, Southern California Edison's experience there has led to a major revamping of computer-system requirements.

Success of subsequent installations at Alamitos and Etiwanda can be attributed largely to lessons learned at Huntington Beach. The five most important are:

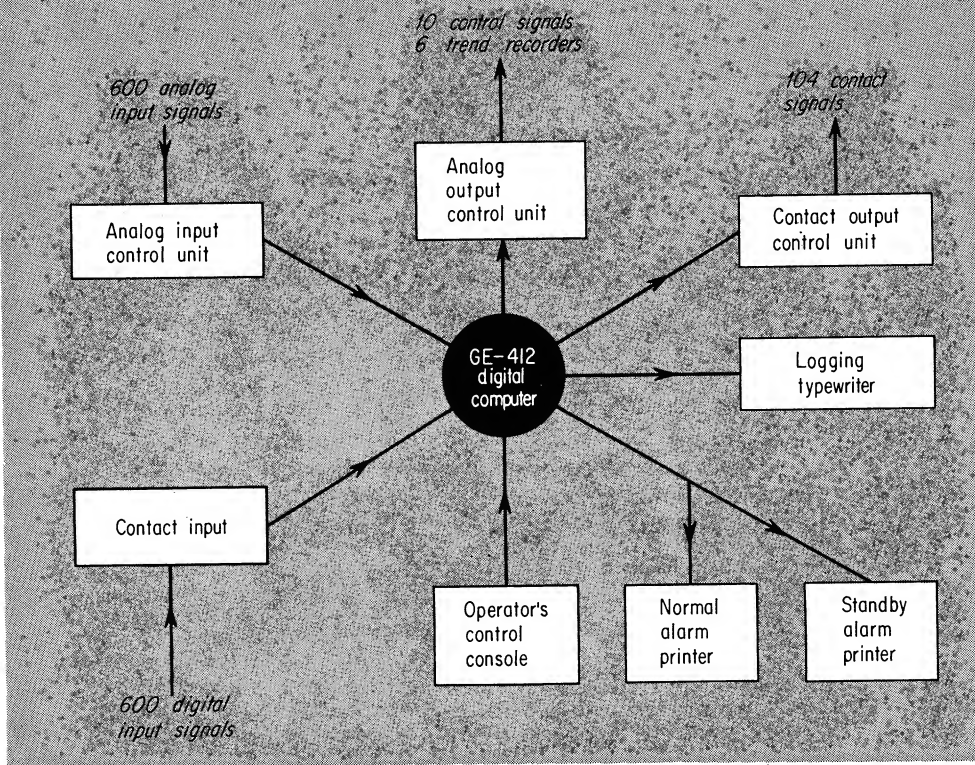
- (1) Complete analysis of system must be carried out before specifying computer requirements.
- (2) Accuracy of critical measuring and actuating devices (pressure, temperature and flow) should be no less than $\pm 0.25\%$ of the measured variable.
- (3) Simulation testing must be carried out in the manufacturer's works; program debugging and documentation should also be complete before installation.
- (4) Control programs must be flexible and easily changed.
- (5) Extensive personnel education and training pays dividends far greater than its cost.

Two contrasting approaches to this latter need are illustrated by recent installations of Westinghouse PRO-DAC 510 computers; Georgia Power Co, whose operators are already familiar with previous installations, felt that no major training program was necessary. Pacific Gas and Electric, on the other hand, with no comparable experience to draw on, insured that all operators at its Contra Costa plant took part in a full training program—amply justified when units 7 and 8 made their initial roll under computer control.

Importance of adequate customer education cannot be overemphasized. If they have not been fully trained in its use, operating personnel can make or break any computer system, particularly at a time of emergency or plant malfunction. The aim of all computer manufacturers is complete automatic control without human intervention. Nevertheless, the guiding rule, "When in doubt, let the operator run the plant," still applies, especially in such hazardous conditions as power plant operation or steel-making. The computer, therefore, in addition to its monitoring functions, must provide the operator with information on plant status and trends. Only in this way can he be continuously aware of minute-by-minute plant conditions, readily able to override or assist the computer.

Winning operator's confidence has often proved an unexpected problem. Experienced plant operating personnel, trained to master the vagaries of a complex process plant, are often unable to understand how a newly-installed computer functions. Input signals from faulty plant equipment can cause a shutdown which, in the operator's eyes, is computer malfunction. Many off-normal data input signals are given unrealistic limits in the program. Consequently, the computer gives erroneous alarms and may even shut down the plant. Experience has shown that careful review of such variables enables non-valid alarms to be eliminated or the limits widened, increasing operators' confidence in the computer system.

Etiwanda unit 4...

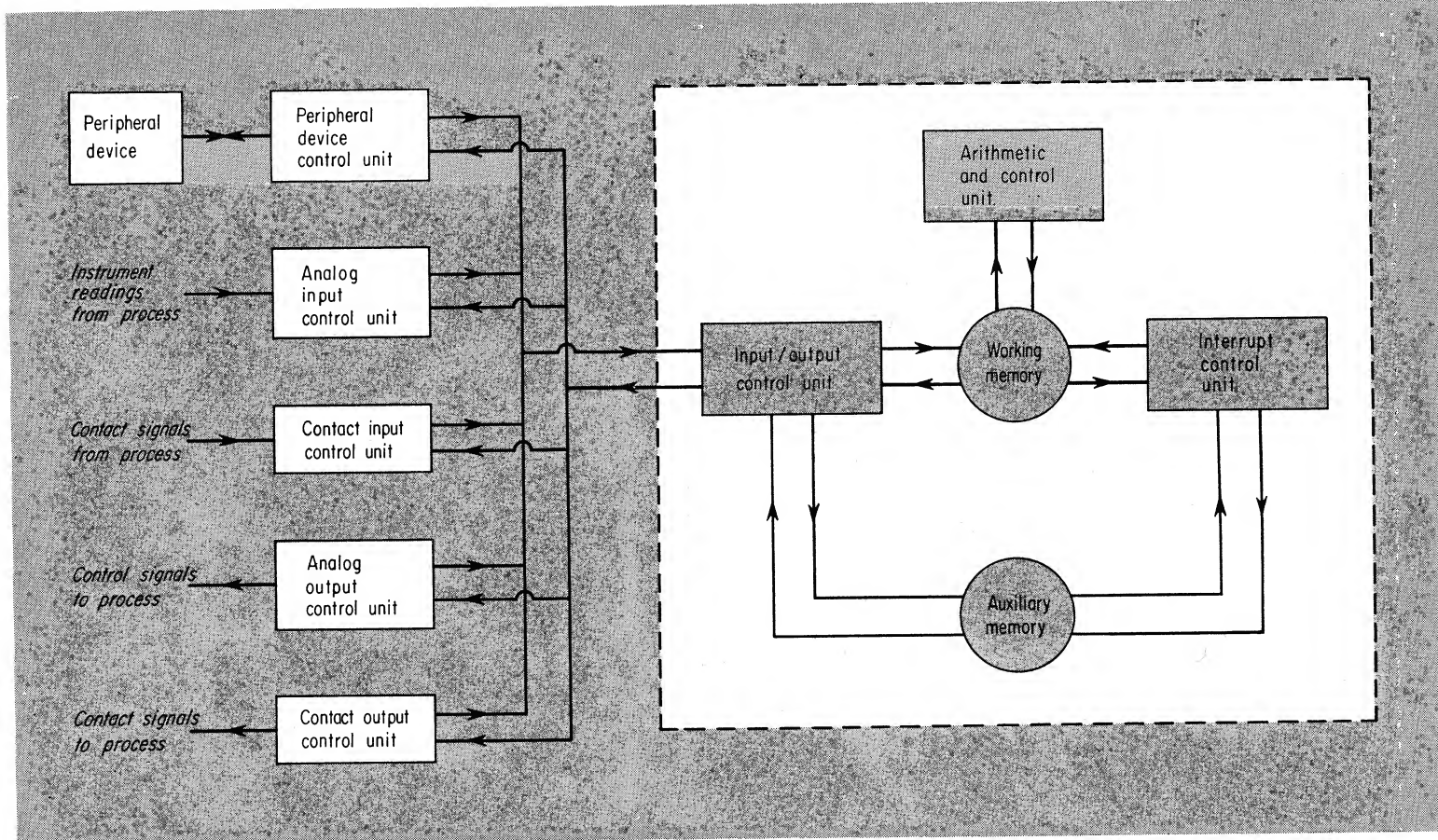


BLOCK DIAGRAM of computer control system installed at McDonough plant. Computer receives 1200 input signals from sensors and transducers, sends out 120 control signals

Ultimate aim in application of process-control computers is to have the computer solely responsible for all plant operations from startup to shutdown. Despite complexity of modern thermal power plants, central-station computers approach this ideal more closely than in comparable industrial applications.

On previous page we outlined the factors to be considered before a computer installation can be specified. But while Georgia Power limits its McDonough computer system largely to plant monitoring, Southern California Edison's 310-mw Unit 4 at Etiwanda is the first to be under full computer control from light-off to line synchronization at operating load.

Based on previous installations (not all successful) at its Huntington Beach and Alamos plants, Southern California Edison has concentrated much experience into the new Etiwanda control system. Using a GE-412 digital



LOGIC CAPABILITY of process-control computers requires some combination of all the units shown above. Computer itself consists of

equipment within dotted line; peripheral devices include tape and card readers and logging typewriters, all aiding the operator

... 12 months of successful computer control

computer basically identical to that installed at McDonough, the automatic control system

- confirms that prestart conditions (temperatures, water levels, valve settings, furnace condition and water treatment) are in accordance with programmed settings

- performs turbine trip tests
- establishes water circulation and air flow through the furnace

- lights and monitors burners

- phases turbine h-p and l-p shafts
- accelerates turbine up to 3600 rpm, synchronizes unit to system frequency, and loads generator to 65 mw.

During operation the computer continuously scans 1084 functions for possible alarm conditions, logs 56 values every half-hour or on demand, and makes 22 performance calculations which vary in complexity from simple totalization to determining net heat rate. Operator is thus relieved of most

routine responsibilities and has more time to optimize plant performance. Should he require a continuous trend recording of any of the major plant functions, he can monitor it by putting the particular input on one of six trend recorders in the control room.

Should the computer fail, the operator can run the plant with conventional subloop controls; all computer outputs are automatically returned to "normal." Two most complex dynamic control functions handled by the computer are boiler warmup and turbine speed control. Experience with the latter at Huntington Beach, where it was controlled as a separate subloop, suggested that the Etiwanda speed control be handled as a closed loop directly through the computer, with contact outputs operating the turbine stop-valve and bypass valve motors to raise or lower turbine speed.

Boiler warmup is computer-controlled

from light-off to full rated pressure. One analog output regulates fuel-valve opening while another adjusts the steam pressure set point after turbine synchronization. Six fuel-change routines are also programmed into the computer to initiate and monitor transfer from gas to oil firing and vice-versa. A further diagnostic and control routine handles emergency transfer to oil firing if gas supply should fail.

Emergency shutdown routines include reinitiation of the scanning program after a trip to remove scan points that could cause false alarms. Considerable extra capacity is available for future refinements dictated by experience. Normal and backup power supplies to the computer are provided by its own ac motor and battery-powered dc motor/ac generator set. At present Etiwanda 4, with only routine maintenance, has been under successful computer control for some twelve months.

Modular concept insures computer-system flexibility

Typical process-control system includes a wide variety of electronic equipment, as shown in the block diagram at left. Generally considered as part of the computer are arithmetic/control unit, working and auxiliary memories.

Arithmetic and control portion of the digital computer provides the logic and calculation capacity needed to evaluate and control output signals to the process plant. Working with instructions from the memory unit and data from sensors and transducers measuring plant conditions, the arithmetic unit performs calculations according to programmed instructions and transmits the results to the input/output control unit.

Memory unit contains instructions, usually as magnetic signals on core or drum, which cause computer to perform the required functions. Storage is also provided for data required to solve calculations, normally programmed into the memory, and for data transmitted from instrumentation within the plant.

Interrupt control unit provides the necessary signals to the arithmetic and control unit when plant situation warrants interruption of the program for priority action. This unit stops normal sequence of instructions within the arithmetic unit and, after noting the point of interruption, triggers entry to the higher priority routine. Normal sequence is resumed automatically.

Many peripheral devices may be linked with the computer. These include magnetic tape, paper tape and card readers, teletype printer, line printer and typewriter. Use is self-explanatory; each has access to a control unit con-

taining the circuitry necessary to transmit information to or from the working memory.

Contact-input control unit provides circuitry to transmit the status of contacts located throughout the plant (limit switches, pressure switches, etc) into the computer memory. This input is in digital form, suitable for immediate use in the computer.

Analog/digital converter selects input signals in analog form (voltages representing pressures and temperatures, for example), amplifies and converts the signals to digital form, then transmits them to the computer memory in the same way as contact-input unit.

Output-control units are similarly either analog or digital (contact). The latter transmits signals to control on/off equipment and certain peripheral devices. Analog control sends out variable-voltage signals to set electrical controllers throughout the plant or to position valves, thus providing closed-loop capability of the computer-control system. Analog outputs are also used for trend recording and other noncontrol functions.

Direct digital control (DDC) is at present much in the news as a likely replacement for analog control. Major advantage is that DDC would abolish need for digital/analog converters and give computer more direct control over plant equipment, as well as remove one more source of spurious signals. However, until we have plant equipment which will respond to DDC signals, analog control will continue to be the principal medium for transmitting computer commands to inplant actuators.

Computer programming can make or mar control system

When specifying a computer-control installation, an important consideration is to insure that hardware and software are complementary. Inclusion of certain hardware features may save much work when programming the computer. Conversely, their absence may render certain instructions impossible to program. By properly weighing the cost of hardware against likely future programming requirements, proper balance can be established between the two sets of costs.

For example, in a situation where large memory capability is required, most economical solution is often to supplement the expensive high-speed "working" memory with a lower-cost auxiliary memory. This combines the advantage of high-speed arithmetical operations with relatively low overall memory cost. Typically, working memory would be magnetic core, and the auxiliary memory either disk, drum or magnetic tape.

Anticipate future expansion

Future needs must be forecast as accurately as possible when specifying a computer system. In many early process-computer installations, programming costs were extremely high because of hardware limitations. Memory was often too small, arithmetical operation slow, and input/output capability limited. Today's computer hardware has helped reduce programming costs considerably, but program changes and possible future expansion should still be taken into account before finalizing design.

In process-control work certain aspects of programming warrant extra consideration. These include real-time operation, memory capability and operator misuse. As a process computer functions in a real-time environment, a certain amount of "free" time must be available to allow for emergency reactions and special operator requests. A good rule of thumb is to allow 40% of free time within the computer; any less may cause the computer program to fall out of step with the operating situation.

Choose memory system with care

Memory capability, as mentioned previously, needs careful balance between working and auxiliary store capacity. System employing fast-working memory, supplemented by large but slow bulk storage memory, is economic compromise but presents problem of data transfer from one to the other. In such a system care must be taken in deciding which functions should remain in working memory at all times and which should be called in from store, as required.

Choice of program language is limited in practice to three: COBOL, ALGOL and FORTRAN. The first, Common Business-Oriented Language, was developed largely as a means of communicating computer functions in the field of business data processing.

ALGOL (Algorithmic Language) is a symbolic language independent of the particular computer structure. A program written in ALGOL is sufficiently legible for a

programmer to read visually, yet, at the same time, may be translated automatically into any particular machine code by a suitable translator program.

Most process-control computers today use one of the variants of IBM's original FORTRAN. Prior to this, writing commands for a computer was a manual process. FORTRAN is, in fact, a compiler or program generator which produces a program automatically suited to the computer in use. Disadvantage is that any compiler-produced program requires about double the space needed by a carefully hand-written program. Thus, a boiler/turbine startup program can be written by hand in some 2000 words but takes 4000 words when produced by a compiler. FORTRAN finds principal applications in relatively infrequent procedures, such as plant startup and shutdown. Minute-by-minute scanning, on the other hand, is handled by a standard "scan, monitor and alarm" program filled in manually for the particular scanning sequence dictated by operating requirements.

Check validity of input signals

Self-checking program is important feature of process-control computer system. Unlike a scientific program in which the results obtained are printed out for perusal by an engineer, closed-loop control system utilizes the computer's calculations to act directly on the process plant itself. Should either input to the computer or data-handling within it be in error, the resulting calculated control points and output signals will be incorrect and could result in hazardous operation. Double and triple checks may be necessary to insure that operating data is valid. As more and more input signals are utilized, the programming necessary to provide such validity checks becomes increasingly more complicated. Continuous calculation of, say, heat balance can be useful in determining the validity of input information, since an extensive range of input data figures in the calculation.

Knowing the process itself is an important attribute of the system programmer. He can observe the overall relationship between program and process more easily, to establish the optimum frequency of data-logging, for example. Also, he can incorporate such aids to efficiency as fixed-point programming where this will speed up a repetitive loop function. For this reason, the present tendency among users is to train their own engineers as programmers rather than rely entirely on the computer manufacturer. To this end manufacturers provide comprehensive training courses—the Westinghouse Computer Center, for example, includes a self-contained school where customers' personnel may spend up to a year studying programming techniques.

Utilities, in particular, have found it essential that programmers be completely familiar with the power plant and its operation. Most of them now assign temporary potential programmers to the manufacturers' works, both to study and also to assist the manufacturers' own staff in an advisory capacity as problems arise.